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Biber et al.

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(54) **COIL POSITION DETECTION**

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G01B 7/30 (2006.01)
G01R 33/02 (2006.01)

(52) **U.S. Cl.**
USPC **324/207.13**; 324/207.15; 324/207.16; 324/207.17; 324/309; 324/318; 324/200; 600/422; 600/407; 600/410

(58) **Field of Classification Search**
USPC 324/207.15–207.17, 309, 318, 200; 600/422, 407, 410
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,304,492 A * 2/1967 Glarum 324/316
3,495,160 A * 2/1970 Salvi et al. 324/301
4,339,953 A * 7/1982 Iwasaki 73/654
4,739,267 A * 4/1988 Leroux et al. 324/314
5,001,428 A * 3/1991 Maier et al. 324/309
5,079,504 A * 1/1992 Machida 324/309
6,223,065 B1 * 4/2001 Misic et al. 600/410
6,396,272 B1 * 5/2002 Dietz et al. 324/318
6,900,636 B2 5/2005 Leussler
7,002,347 B2 * 2/2006 Feiweier et al. 324/318
7,006,676 B1 * 2/2006 Zeylikovich et al. 382/131
7,075,299 B1 * 7/2006 Peters 324/309
7,141,976 B2 * 11/2006 Campagna 324/318
7,266,406 B2 * 9/2007 Kroeckel 600/410
7,382,127 B2 * 6/2008 Gaddipati et al. 324/309
7,486,077 B2 * 2/2009 Hergt et al. 324/318
8,258,787 B2 * 9/2012 Fischer et al. 324/318
2002/0042567 A1 * 4/2002 Heid 600/410
2002/0169374 A1 * 11/2002 Jevtic 600/422
2002/0198448 A1 * 12/2002 Zuk et al. 600/414
2003/0231018 A1 * 12/2003 Willig-Onwuachi et al. 324/318
(Continued)

FOREIGN PATENT DOCUMENTS

JP 2010162332 * 7/2010
JP 20101623332 A * 7/2010

OTHER PUBLICATIONS

Soliman et al., "Continuous and Discrete Signals and Systems", Prentice Hall, 1990, pp. 1-6.*

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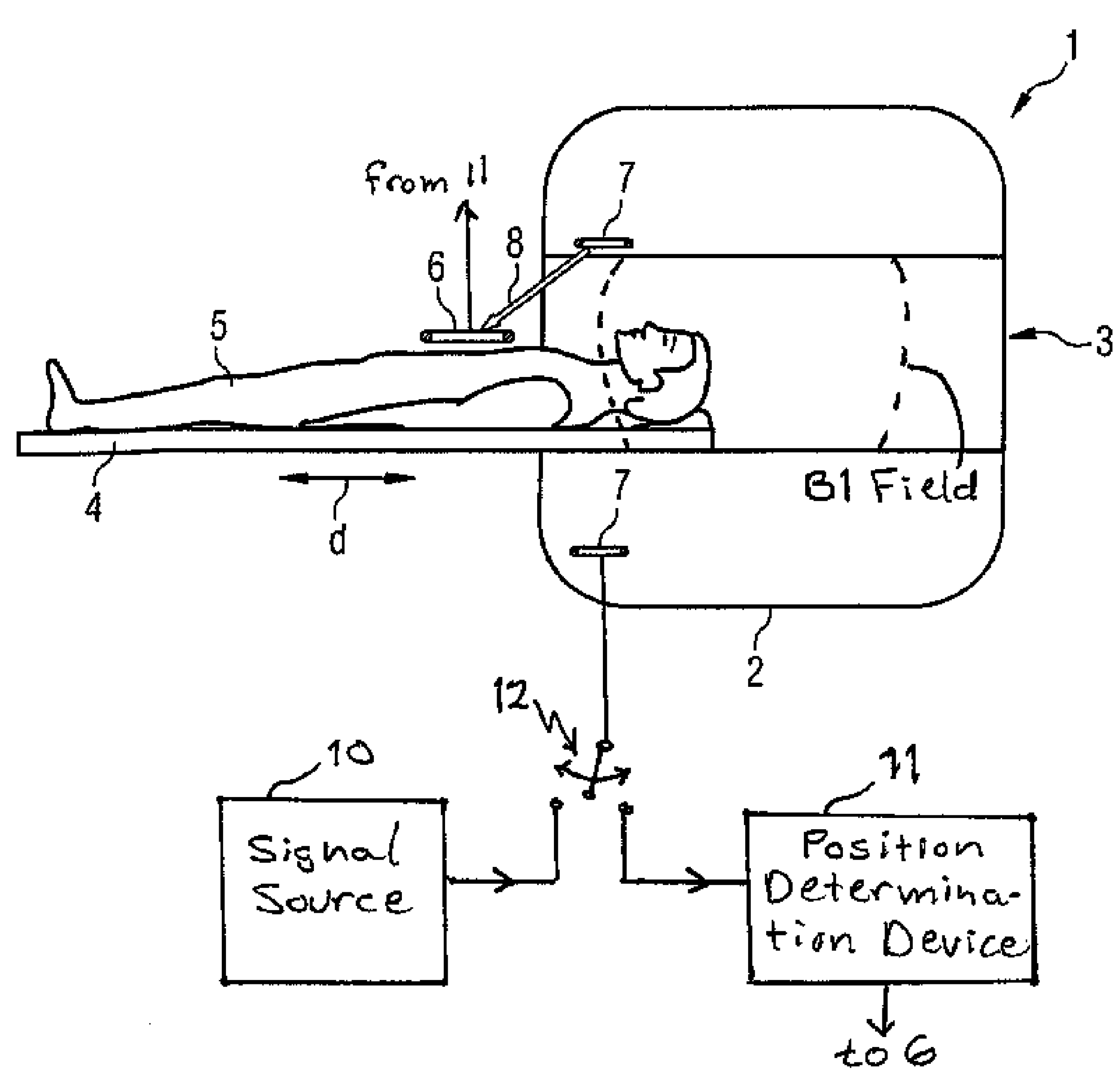
(57) **ABSTRACT**

A simple position determination is enabled by a device and a method to determine the position of a local coil in a magnetic resonance apparatus, wherein at least one signal emitted by at least one transmission coil is received by the local coil and is evaluated with a position determination device in order to determine the position of the local coil.

22 Claims, 3 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2004/0032263	A1*	2/2004	Renz	324/318
2004/0116797	A1*	6/2004	Takahashi et al.	600/407
2005/0179433	A1*	8/2005	Wiesinger et al.	324/309
2005/0264288	A1*	12/2005	Campagna et al.	324/309
2005/0272998	A1*	12/2005	Diehl et al.	600/410
2006/0108998	A1*	5/2006	Van Zundert et al.	324/200
2006/0250133	A1*	11/2006	Krieg et al.	324/318
2006/0273796	A1*	12/2006	Kuth et al.	324/318
2007/0222445	A1*	9/2007	Hertz et al.	324/307
2007/0229076	A1*	10/2007	Habara et al.	324/318
2008/0033278	A1*	2/2008	Assif	600/410
2008/0068016	A1*	3/2008	Gaddipati et al.	324/318
2008/0088309	A1*	4/2008	Eberler et al.	324/318
2008/0097189	A1*	4/2008	Dumoulin et al.	600/410
2008/0211503	A1*	9/2008	Arnold et al.	324/318
2008/0218168	A1*	9/2008	Takagi	324/309
2008/0224701	A1*	9/2008	Okamoto	324/318
2008/0272785	A1*	11/2008	Crozier et al.	324/318
2008/0275333	A1*	11/2008	Fain et al.	600/422
2009/0052760	A1*	2/2009	Smith et al.	382/132
2009/0264735	A1*	10/2009	Steckner	600/422
2009/0315556	A1*	12/2009	Driemel et al.	324/307
2010/0052682	A1*	3/2010	Mueller	324/318
2010/0072997	A1*	3/2010	Fischer et al.	324/309
2010/0152568	A1*	6/2010	Kokubun	600/410
2010/0156412	A1*	6/2010	Biber et al.	324/307
2010/0182005	A1*	7/2010	Biber	324/307
2010/0228117	A1*	9/2010	Hartmann	600/424
2010/0256480	A1*	10/2010	Bottomley et al.	600/411
2010/0271027	A1*	10/2010	Biber et al.	324/318
2010/0292559	A1*	11/2010	Hannemann et al.	600/407
2011/0092792	A1*	4/2011	Birman	600/407
2011/0109315	A1*	5/2011	Biber et al.	324/318

* cited by examiner

FIG 1

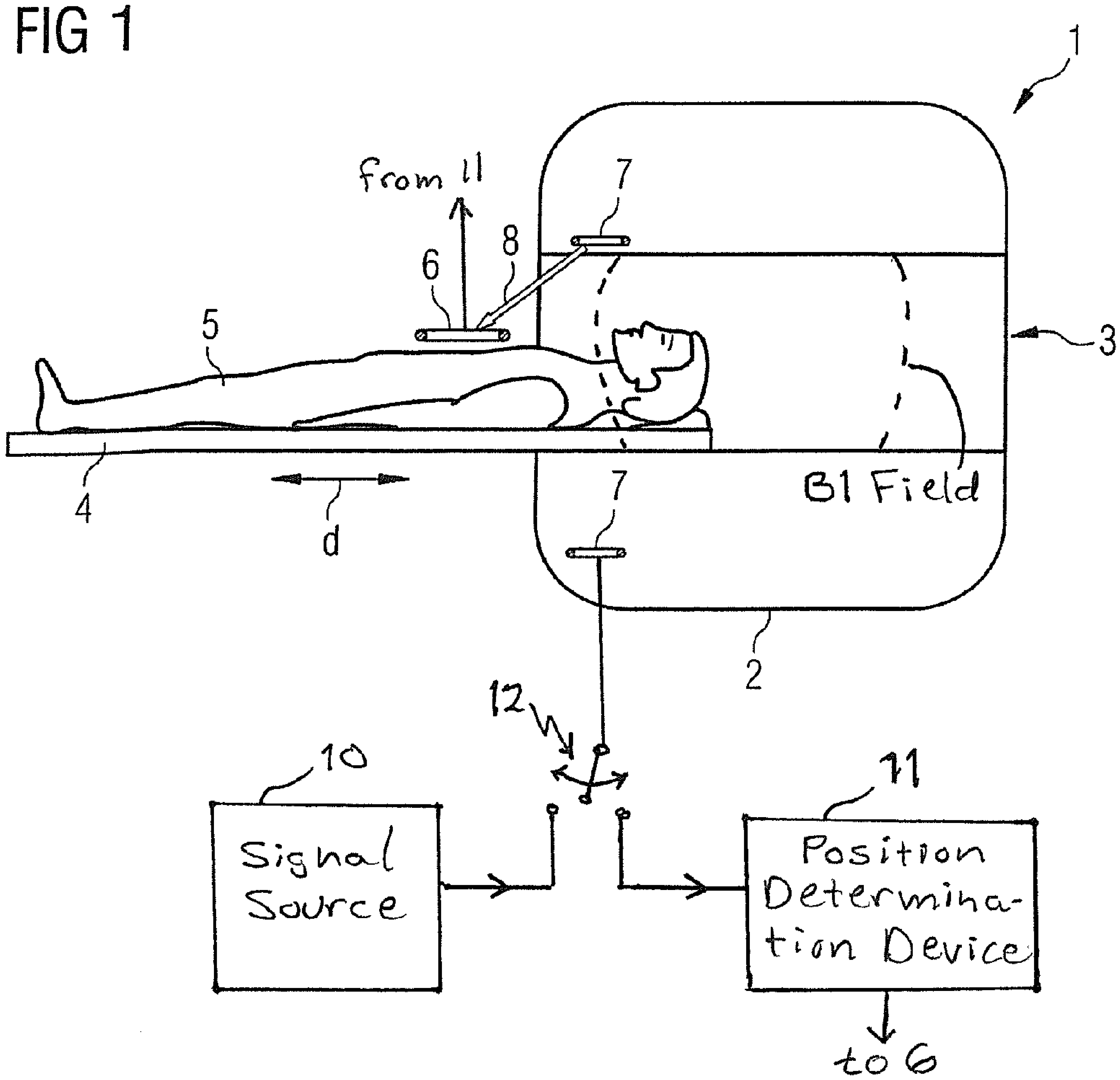

1
from 11
7
8
6
5
3
4
d
7
B1 Field
2
12
10
Signal Source
11
Position Determination Device
to 6

FIG 2

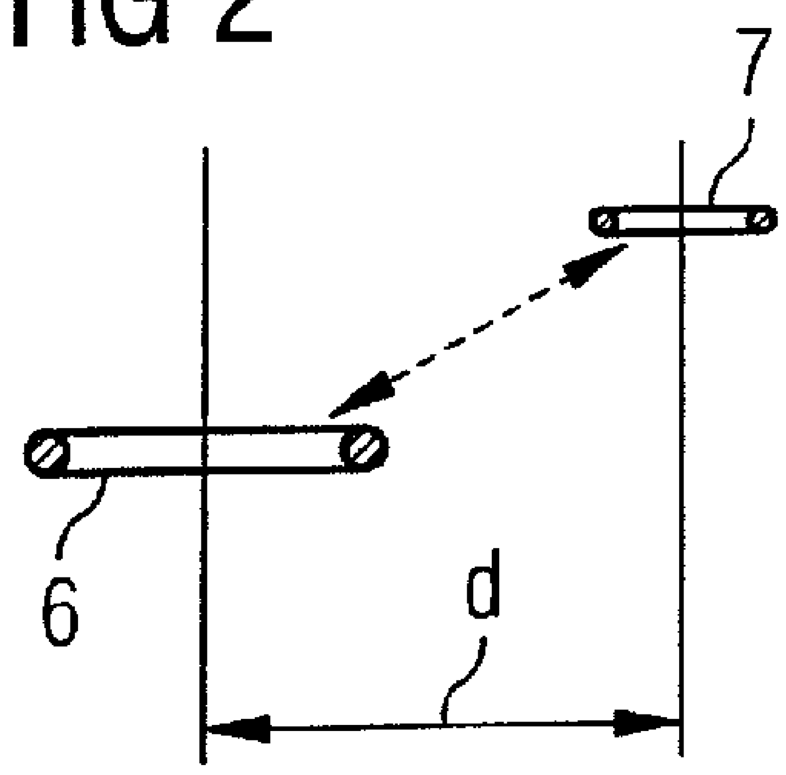


FIG 3

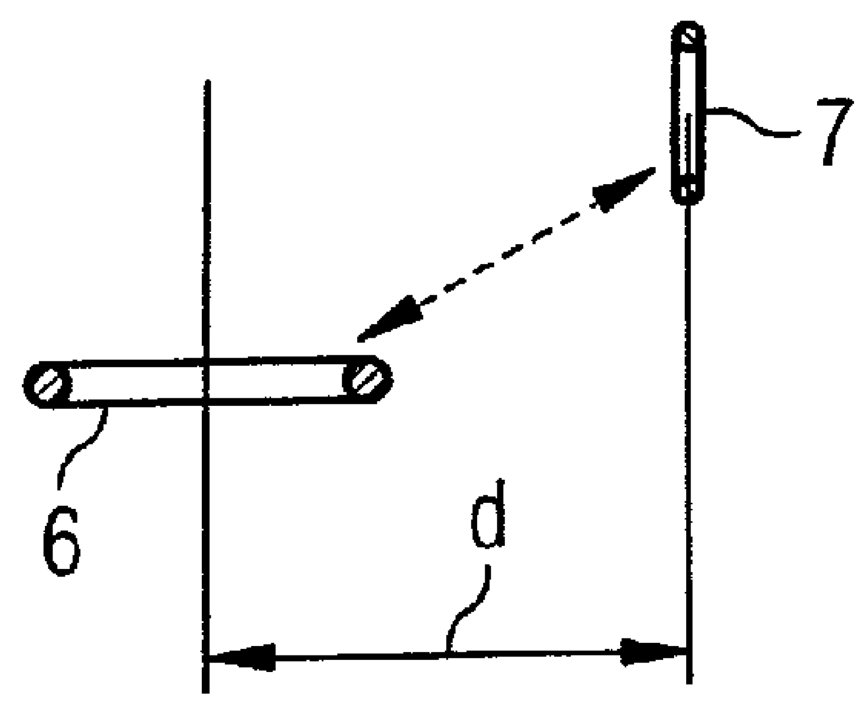


FIG 4

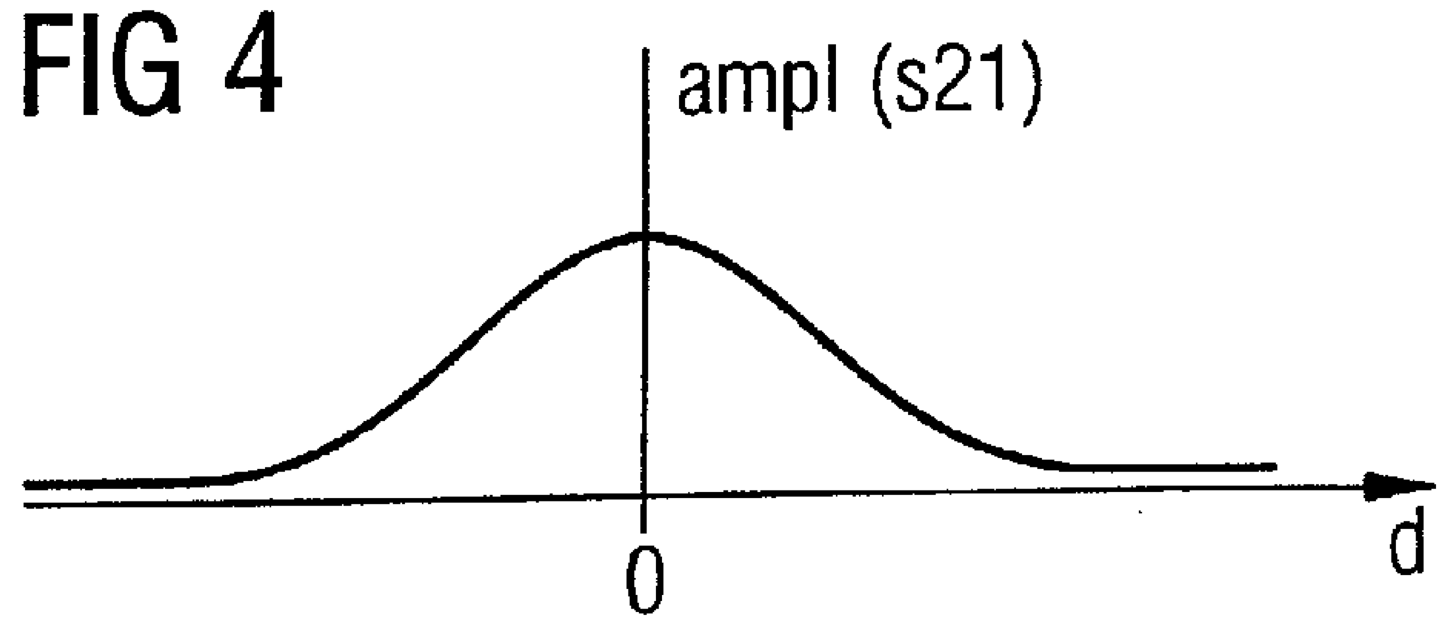


FIG 5

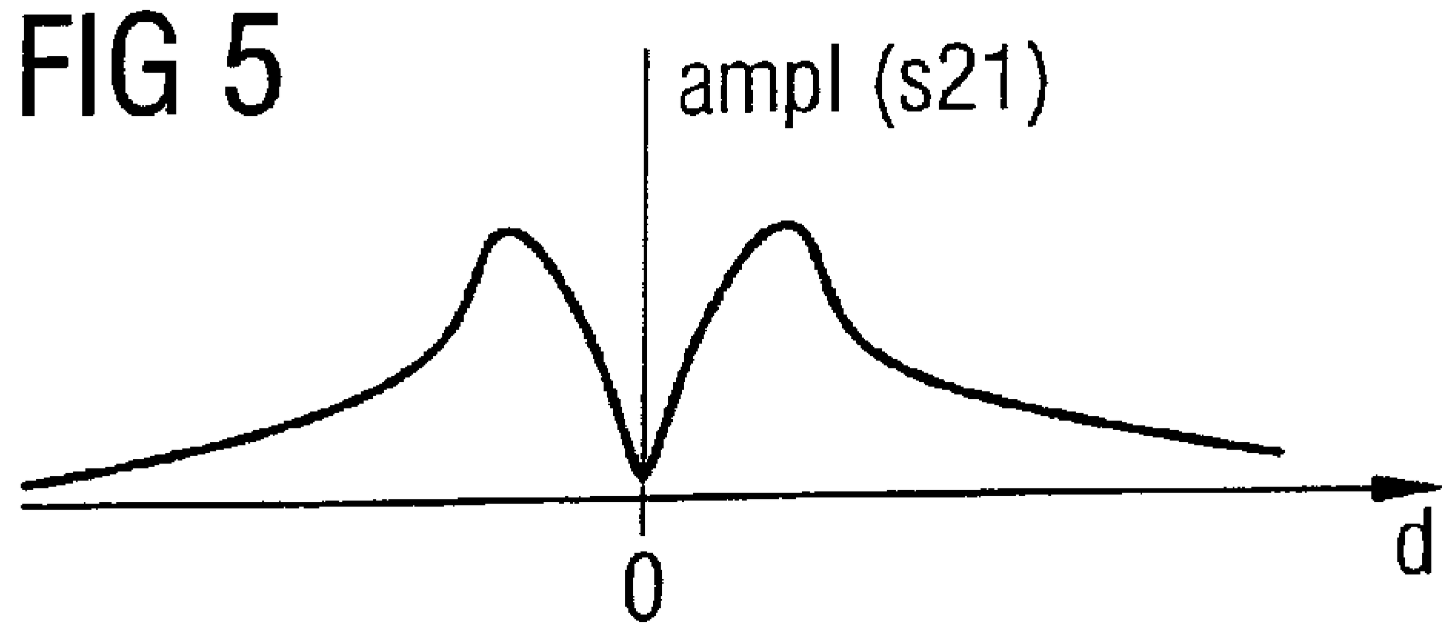


FIG 6

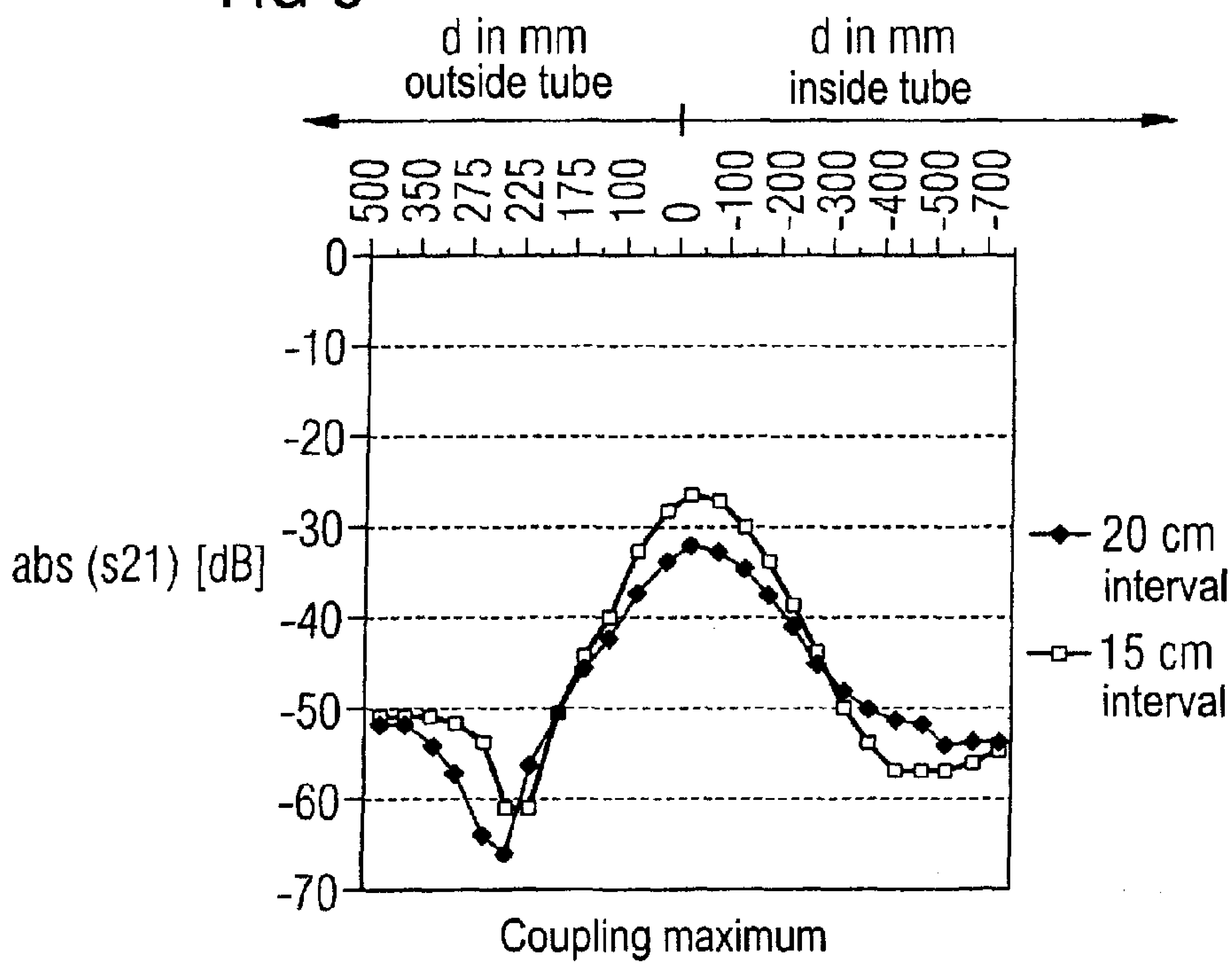
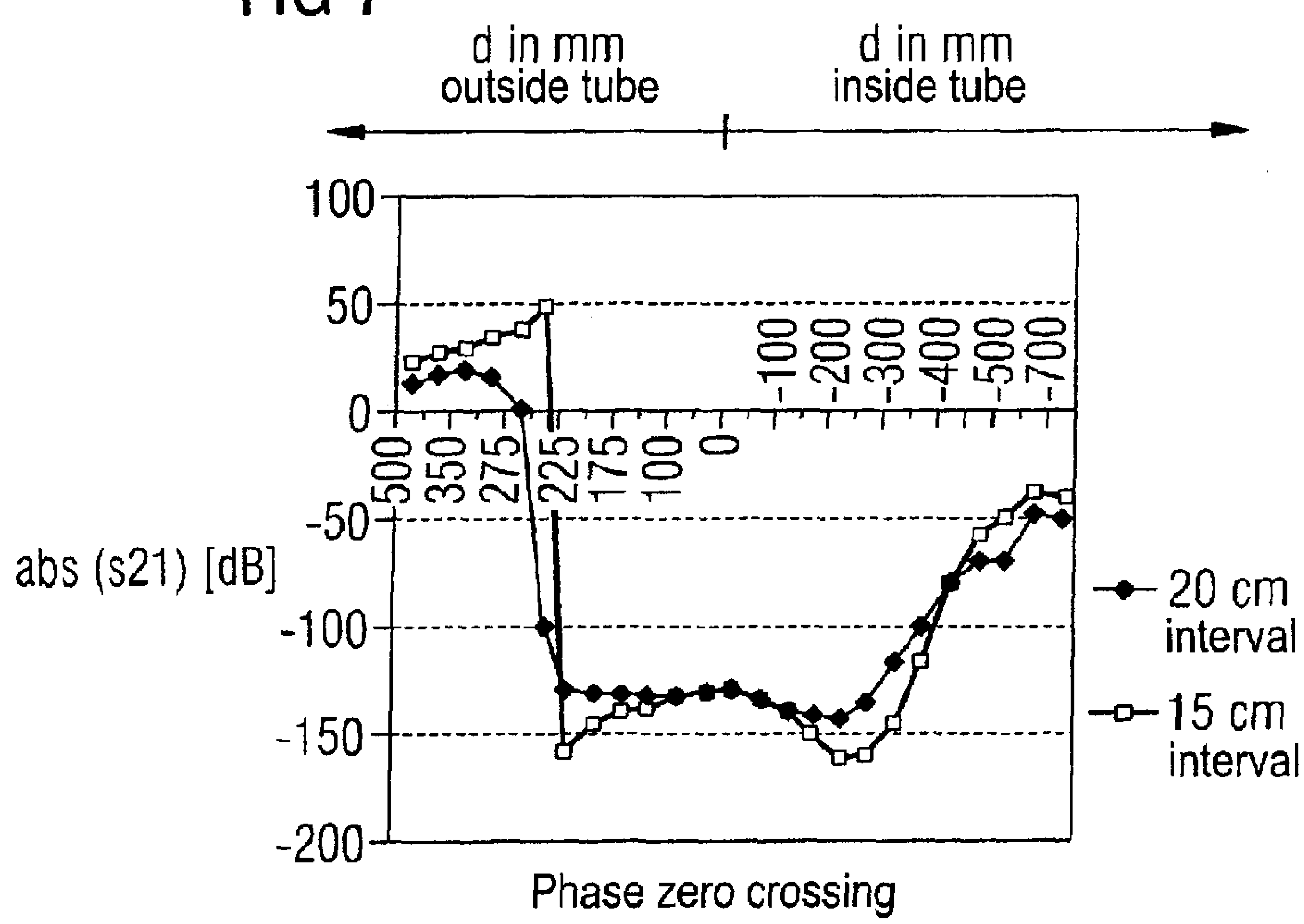

d in mm
outside tube
d in mm
inside tube
500
350
275
225
175
100
0
-100
-200
-300
-400
-500
-700
0
-10
-20
-30
-40
-50
-60
-70
abs (s21) [dB]
20 cm
interval
15 cm
interval
Coupling maximum

FIG 7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outside tube
d in mm
inside tube
100
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0
-50
-100
-150
-200
500
350
275
225
175
100
0
-100
-200
-300
-400
-500
-700
abs (s21) [dB]
20 cm
interval
15 cm
interval
Phase zero crossing

COIL POSITION DETECTION

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention concerns methods and devices for the determination of the position of a local coil for a magnetic resonance apparatus.

2. Description of the Prior Art

Magnetic resonance apparatuses for examination of patients, in particular by means of magnetic resonance tomography are known from DE 10 342 15B4, for example.

Modern magnetic resonance systems normally operate with multiple different antennas (also called coils in the following) to emit radio-frequency pulses for nuclear magnetic resonance excitation and/or to receive the induced magnetic resonance signals. A magnetic resonance system typically has a larger coil that is normally permanently installed in the apparatus, known as a whole-body coil (also called a body coil or BC), as well multiple small local coils (also called surface coils or LCs). In contrast to the whole-body coil, the local coils serve to acquire detailed images of body parts or organs of a patient that are located relatively near to the body surface. For this purpose the local coils are applied directly at the point of the patient at which the region to be examined is located. Given a use of such a local coil, in many cases the transmission occurs with the whole-body coil (as transmission coil) permanently installed in the magnetic resonance system and the induced magnetic resonance signals are received with the local coil (as reception coil).

The position of local coils used to receive the MR signals in the medical MR imaging can vary relative to the patient table and to the patient. Optical detection with a camera and RFID methods has been considered as solution approaches to determine the position. An additional known method uses the MR imaging itself in order to localize the coils. Disadvantages of the optical detection and the RFID method are the necessary additional components in the coil and/or in the MR scanner that incur costs. Disadvantages of the MR imaging are the time cost (a separate measurement is required for every bed (patient) position) and the problematic reliability (dependency on MR imaging parameters, for example B0 homogeneity, B1 homogeneity, in particular at the edge of the imaging volume).

SUMMARY OF THE INVENTION

An object of the present invention is to enable an optimally efficient determination of the position of a local coil of a magnetic resonance apparatus.

According to the invention, a device to determine the position of a local coil for a magnetic resonance apparatus, has a local coil to receive a signal emitted by at least one transmission coil, and a position determination device to evaluate the signal and determine from this signal the position of the local coil.

According to the invention, a method is also provided to determine the position of a local coil for a magnetic resonance apparatus, wherein at least one signal emitted by at least one transmission coil is received by the local coil and evaluated with a position determination device in order to determine the position of the local coil.

An advantage of the invention is the utilization of components that are generally already present for the position determination, which can yield a cost advantage. Even if an additional pickup coil were to be used for the new method instead of an existing coil, this component is extremely cost-effective since the entire activation and signal generation system is already present in the scanner (it can be operated at the MR transmission frequency).

Possible interferences with or negative effects on the measurement workflow are avoided since no additional time is required for a coil position detection, as in known MR methods.

A simple determination of the position of these local coils entails advantages for the system operation. For example, given a known position of the local coils it is possible to assign a reasonable combination of reception coils with measurement protocols automatically (without interaction with the user). Coils that are far removed from the imaging volume do not improve the SNR of the image, but rather to the contrary increase the noise level or intensify image artifacts (ambiguity artifacts—"third arm") and therefore should not be activated. Furthermore, the known position of the local coils allows a measurement protocol to determine the possibilities (acceleration factors and directions) of the parallel imaging. This information can be used for an automatic determination of optimal acquisition parameters, for example, or be provided to the user in a suitable manner (limitation or suitable display of the reasonable range of protocol parameters).

In particular, a determination of the coil position is accomplished by measurement of the coupling of one or more (advantageously small) transmitting coils relative to at least one local coil upon driving the bed into the patient tunnel. A determination of the position of the local coil relative to the stationary transmitting coupling coil can ensue by evaluation of the signal, in particular by measurement of the amplitude and/or phase of the coupling of the two coils depending on the bed position (z-profile) and a maximum or zero crossing evaluation of the amplitude and/or phase.

In the event that, according to an embodiment of the invention, not just one but rather multiple coils are used as transmission coils, the precision of the measurement can be increased, or not only a z-position detection but also a detection of the azimuthal position can ensue.

According to an embodiment of the invention, the pickup coils of the body coil that are already present in many MR systems (which pickup coils serve to detect the body coil B1 fields in MR transmission operation) can be used for the transmitting coupling coils. The pickup coils have previously not been used during the insertion of the bed and could advantageously be connected alternately with a receiver device or with a signal source by crossover switches.

In addition to a co-planar arrangement of a transmitting coil relative to the local coil according to one embodiment of the invention, according to an additional embodiment of the invention an orthogonal arrangement of at least one transmitting coil relative to the local coil is also advantageous. It offers the advantage of a sharp zero crossing of the coupling amplitude as well as a detection of the structure of the local coil given advantageous geometric relationships.

In another embodiment of the invention, wherein a multi-channel transmission array is present in the tomography device, its elements are used in place of the pickup coils.

If, according to another embodiment of the invention wherein multiple transmission coils are used for coil detection, the signals can be differentiated, for example via different transmission frequencies or via a multiplexing (temporally offset transmission with the individual coils).

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 schematically illustrates an MRT whole-body coil and a local coil whose position is to be determined.

FIG. 2 shows a co-planar arrangement of a transmission coil and a local coil.

FIG. 3 shows an orthogonal arrangement of a transmission coil and a local coil.

FIG. 4 shows an amplitude curve in the local coil in an arrangement according to FIG. 2.

FIG. 5 shows an amplitude curve in the local coil in an arrangement according to FIG. 3.

FIG. 6 shows amplitude curves in the local coil.

FIG. 7 shows phase curves in the local coil.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 shows a magnetic resonance apparatus MRT **1** with a whole-body coil **2** with a tubular space **3** into which a patient bed **4** (with a patient **5** and a local coil **6**, for example) can be driven in order to generate exposures of the patient **5**. Here a local coil **6**, with which good exposures are enabled in a local range, is placed on the patient **5**.

The position of the local coil **6** should be determined. For this a signal **8** emitted by at least one transmission coil **7** is received and evaluated with a position determination device **11** connected with the local coil **6** and the transmission coil **7** (and possibly the whole-body coil **2**) directly or via other elements by schematically represented connections. With the position determination device **11**, the position (relative to the transmission coil and, therefore, possibly relative to the patient bed and/or the patient and/or to the MRT whole-body coil) of the local coil **6** can be determined.

For position determination, the amplitude and/or phase of signals sent by at least one transmission coil **7** and received in the local coil **6** is evaluated in the position determination device **11**.

The signal emitted by a transmission coil can also be a signal emitted specifically to enable the position determination of a local coil and/or a signal that is used only for this purpose.

The transmission coil or transmission coils and the local coil can be arranged coplanar to one another according to FIG. 2 (thus pointing in the same direction) or orthogonal to one another according to FIG. 3 (thus point in directions orthogonal to one another).

In a co-planar arrangement according to FIG. 2, during a movement of the patient bed with the local coil **6** in the longitudinal direction (d) of the whole-body coil (thus into this), the amplitude curve according to FIG. 4 results during the movement, wherein the position of the local coil at d=0 (thus when the local coil **6** is located under the transmission coil) can be determined well with a maximum detection (which position can be used given a further movement of the patient bed by a specific distance), possibly under consideration of this to calculate a new position of the limit value. If the transmission coil **7** is located approximately at the left end of the whole-body coil **2** in FIG. 1, for example, in which patient bed position the local coil **6** is located there can thus be determined. This position of the local coil can be used in order to later associate from it signals received from the whole-body coil in the imaging operation (or ii determined from said signals) with a position of the bed or of the whole-body coil or in the patient.

Given an orthogonal arrangement of the coils **6**, **7** relative to one another according to FIG. 3, during a movement of the patient bed with the coil in the longitudinal direction (d) of the whole-body coil (thus into this) the amplitude curve ampl (s**21**) according to FIG. 5 results during the movement, so the position of the local coil at d=0 (thus when the local coil **6** is located under the transmission coil) can be determined well with an amplitude minimum detection (which position can be used to calculate a new position given a further movement of the patient bed by a specific distance, possibly to intentionally reach this new position). If the transmission coil **7** is located at the left end of the whole-body coil **2** in FIG. 1, for example, the patient bed position, or where relative to the patient or to the whole-body coil etc. the local coil **6** is located, can be determined.

FIG. 6 shows an example the measured curve of the amplitude of the signal sent by a transmission coil (which is received in the local coil) during the movement of the local coil **6** (together with the patient bed) in the direction d into the whole-body coil **2**; at d=0 the local coil is thereby below the transmission coil in FIG. 1, thus—given arrangement of the transmission coil **7** at the entrance of the whole-body coil **2**, for instance—at the entrance (or otherwise correspondingly displaced, as is also in FIG. 1 where the transmission coil is somewhat to the right of the entrance). In FIG. 6 the maximum of the amplitude occurs when the local coil is located below the transmission coil. Given a greater distance (20 cm) of the local coil from the transmission coil, given positioning below this the amplitude is somewhat lower than at a smaller distance (14 cm).

In addition to the amplitude of the signal which the local coil **6** receives from the transmission coil **7**, the phase of this signal can also be evaluated.

FIG. 7 shows an example of the measured curve of the phase of the signal sent by the transmission coil and received in the local coil during the movement of the local coil **6** (together with the patient bed) in the direction d into the whole-body coil **2**. In FIG. 7 a zero crossing of the phase shift between the transmission coil and the local coil at a specific position of the local coil is to be detected with the position determination device.

Existing coils, in particular pickup coils of the body coil that serve to detect body coil B1 fields in the transmission operation of the body coil can be used as transmitting coils (here also called coupling coils). The pickup coils have previously not been used during the insertion of the bed and could be connected with a signal source **10** instead of with a receiver device via crossover switches such as switch **12**. In principle, given the presence of a multi-channel transmission array it would also be possible to use its elements in place of the pickup coils.

By the use of more than one transmission coil (at different positions and/or different orientations and/or with different phases of its transmission signal), the position of the local coil can be determined in multiple dimensions. If multiple transmission coils are used for coil detection, their signals can be differentiated in the local coil, for example via different transmission frequencies or via a multiplexing (temporally offset transmission of the individual coils).

Although modifications and changes may be suggested by those skilled in the art, it is the intention of the inventors to embody within the patent warranted hereon all changes and modifications as reasonably and properly come within the scope of their contribution to the art.

We claim as our invention:

1. A device to determine a position of a magnetic resonance local coil of a magnetic resonance data acquisition unit, comprising:

at least one transmission coil associated with a magnetic resonance data acquisition unit, said at least one transmission coil radiating an electromagnetic signal;

a magnetic resonance local coil that receives said electromagnetic signal radiated by said at least one transmission coil and that generates a local coil signal dependent thereon, said local coil signal exhibiting an amplitude and a phase; and

a computerized position determination device in communication with said magnetic resonance local coil that receives said local coil signal therefrom, and that is configured to evaluate said local coil signal to determine a position of the magnetic resonance local coil relative to a selected location associated with said data acquisition unit, by plotting a signal curve of said local coil signal, selected from the group consisting of a signal curve of said phase and a signal curve of said amplitude, with respect to an axis and identifying said position of said local coil directly from an actual zero-crossing of said axis by the signal curve of said local coil signal.

2. A device as claimed in claim **1** comprising a plurality of transmission coils associated with said data acquisition unit that each radiate an electromagnetic signal, and wherein said magnetic resonance local coil detects each of the respective electromagnetic signals and generates respective coil signals dependent thereon, and wherein said position determination device is configured to determine the position of the magnetic resonance local coil from all of said coil signals.

3. A device as claimed in claim **2** comprising a control unit that operates said plurality of transmission coils to radiate said respective electromagnetic signals with different or temporally offset transmission times.

4. A device as claimed in claim **2** wherein said plurality of transmission coils form a multi-channel transmission array.

5. A device as claimed in claim **1** wherein said position determination device is configured to determine the position of the magnetic resonance local coil relative to said transmission coil or relative to said data acquisition unit.

6. A device as claimed in claim **1** wherein said data acquisition unit comprises a movable bed adapted to receive a patient thereon, and wherein said patient determination unit is configured to determine the position of the magnetic resonance local coil relative to the bed or relative to the patient.

7. A device as claimed in claim **6** wherein said bed is displaced through a plurality of bed positions, and wherein said position determination unit is configured to determine said position of said magnetic resonance local coil dependent on said bed position.

8. A device as claimed in claim **1** wherein said at least one transmission coil and said magnetic resonance local coil are oriented co-planar relative to each other.

9. A device as claimed in claim **1** wherein said at least one transmission coil and said magnetic resonance local coil are oriented orthogonally relative to each other.

10. A method to determine a position of a magnetic resonance local coil of a magnetic resonance data acquisition unit, comprising the steps of:

from at least one transmission coil associated with a magnetic resonance data acquisition unit, radiating an electromagnetic signal;

with a magnetic resonance local coil, receiving said electromagnetic signal radiated by said at least one transmission coil and generating a local coil signal dependent thereon, said local coil signal exhibiting an amplitude and a phase; and

supplying a computerized position determination device in communication with said local coil signal and, in said position determination device, automatically evaluating said local coil signal to determine a position of the magnetic resonance local coil relative to a selected location associated with said data acquisition unit, by plotting a signal curve said local coil signal, selected from the group consisting of a signal curve of said phase and a signal curve of said amplitude, with respect to an axis and identifying said position of said local coil directly from an actual zero-crossing of said axis by the signal curve of said local coil signal.

11. A method as claimed in claim **10** comprising, from a plurality of transmission coils associated with said data acquisition unit, individually radiating respective electromagnetic signals and, with said magnetic resonance local coil, detecting each of the respective electromagnetic signals and generating respective coil signals dependent thereon, and in said position determination device, determining the position of the magnetic resonance local coil from all of said coil signals.

12. A method as claimed in claim **11** comprising, from said plurality of transmission coils, radiating said respective electromagnetic signals with different or temporally offset transmission times.

13. A method as claimed in claim **11** comprising employing a multi-channel transmission array as said plurality of transmission coils.

14. A method as claimed in claim **10** comprising, in said position determination device, determining the position of the magnetic resonance local coil relative to said transmission coil or relative to said data acquisition unit.

15. A method as claimed in claim **10** wherein said data acquisition unit comprises a movable bed adapted to receive a patient thereon and comprising, in said patient determination unit, determining the position of the magnetic resonance local coil relative to the bed or relative to the patient.

16. A method as claimed in claim **15** comprising displacing said bed through a plurality of bed positions and, in said position determination unit, determining said position of said magnetic resonance local coil dependent on said bed position.

17. A method as claimed in claim **10** comprising orienting said at least one transmission coil and said magnetic resonance local coil co-planar relative to each other.

18. A method as claimed in claim **10** comprising orienting said at least one transmission coil and said magnetic resonance local coil orthogonally relative to each other.

19. A device to determine a position of a magnetic resonance local coil of a magnetic resonance data acquisition unit, said magnetic resonance data acquisition unit comprising a body coil that radiates a B1 field in said magnetic resonance data acquisition unit, said device comprising:

at least one transmission coil associated with said magnetic resonance data acquisition unit, said at least one transmission coil radiating an electromagnetic signal;

said transmission coil also being configured to detect said B1 field of said body coil;

a magnetic resonance local coil that receives said electromagnetic signal radiated by said at least one transmission coil and that generates a local coil signal dependent thereon, said local coil signal exhibiting an amplitude and a phase; and

a computerized position determination device in communication with said magnetic resonance local coil that receives said local coil signal therefrom, and that is configured to evaluate said local coil signal to determine a position of the magnetic resonance local coil relative to a selected location associated with said data acquisition unit, by plotting a signal curve of said local coil signal, selected from the group consisting of a signal curve of said phase and a signal curve of said amplitude, with respect to an axis and identifying said position of said local coil directly from an actual zero-crossing of said axis by the signal curve of said local coil signal.

20. A device as claimed in claim **19** comprising an automatically or manually operated switch connected to said at least one transmission coil allowing operation of said transmission coil to detect said characteristic of said B1 field or to radiate said electromagnetic signal, dependent on a state of said switch.

21. A method to determine a position of a magnetic resonance local coil of a magnetic resonance data acquisition unit, said magnetic resonance data acquisition unit comprising a body coil that radiates a B1 field in said magnetic resonance data acquisition unit, said method comprising:

operating at least one transmission coil associated with said magnetic resonance data acquisition unit to radiate an electromagnetic signal;

with said transmission coil, also detecting said B1 field of said body coil;

with a magnetic resonance local coil, receiving said electromagnetic signal radiated by said at least one transmission coil and generating a local coil signal dependent thereon, said local coil signal exhibiting an amplitude and a phase; and

in a computerized position determination device in communication with said magnetic resonance local coil that receives said local coil signal therefrom, automatically evaluating said local coil signal to determine a position of the magnetic resonance local coil relative to a selected location associated with said data acquisition unit, by plotting a curve of said local coil signal, selected from the group consisting of a signal curve of said phase and a signal curve of said amplitude, with respect to an axis and identifying said position of said local coil directly from an actual zero-crossing of said axis by the signal curve of said local coil signal.

22. A method as claimed in claim **21** comprising switching operation of said transmission coil between detecting said characteristic of said B1 field or radiating said electromagnetic signal.

* * * * *